The effect of a vee-mapping strategy on students' perceptions of laboratory activities

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THE EFFECT OF A VEE-MAPPING STRATEGY ON STUDENTS' PERCEPTIONS OF LABORATORY ACTIVITIES

by

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A thesis submitted in partial fulfilment of the requirements for the degree of Bachelor of Education with Honours in the Faculty of Education of the Edith Cowan University.

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ABSTRACT

Practical work is considered important for learning science, by teachers and science educators. This acceptance though, has been reported as based on intuition rather than evidence (Atkinson & White, 1981). A significant proportion of class time is occupied with doing practical work.

It is evident that in a majority of situations, students commence laboratory activities unsure of their aim, the procedure they are going to carry out, or that experimentation is a way of forming knowledge (Moreira, 1980; Novak & Gowin, 1984).

Vee-maps (Novak & Gowin, 1984) are one way of making laboratory work more meaningful. That is, by tying new knowledge to existing schemata students will learn more effectively.

Vee-maps concentrate students' attention on the focus question, the event to be observed, and direct students to interpret results in terms of relevant prior knowledge.

In this project the teacher was taught vee-mapping and then incorporated this into his pre-laboratory and post-laboratory discussion.

A one-group pre-test-post-test design was used for this study where, all students (N=13) were pre-tested after traditional instruction, and post-tested after a four week treatment program. Subjects for this study were an existing class of Year 11 Biology students at a Western Australian Senior High School.
Two types of instruments were designed and used for the pre-test and post-test. These instruments gathered information about students' understandings of a particular laboratory, and their perceptions of pre-laboratory and post-laboratory discussions.

Observations were made of the teacher's presentation and he was interviewed for his perceptions of student changes and opinion of implementation.

The results of the study showed that students believed they had gained more from both the pre-laboratory and post-laboratory discussions after the vee-mapping strategy had been implemented. There was a significant gain in their ability to identify pre-requisite concepts of an experiment. However there was no increase in their ability to identify the purpose or the experimental outcomes of a laboratory exercise. The teacher found the vee-mapping strategy easy to implement into the pre-laboratory and post-laboratory discussions.
I certify that this thesis does not incorporate, without acknowledgement, any material previously submitted for a degree or diploma in any institution of higher education and that, to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where due reference is made in the text.

Sonia Jane Hueppauff
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CHAPTER 1: INTRODUCTION

Background

Practical work is considered important to the learning of science, by teachers and science educators, in Australia and many other countries. This acceptance though, has been reported as based on intuition rather than evidence (Atkinson & White, 1981). A significant proportion of science class time is occupied with doing practical work.

It is evident that in a majority of situations students commence laboratory activities unsure of their aim or the procedure they are going to carry out. Further, they apparently have no understanding that experimentation is a way of forming knowledge (Moreira, 1980; Novak & Gowin, 1984).

Vee-maps (Gowin & Novak, 1984) are one way of making laboratory work more meaningful. Vee-maps concentrate students’ attention on the focus question, the event to be observed, and direct students to interpret results in terms of their prior knowledge. This process assists students to obtain an overall view of the laboratory exercise and to see how theory is linked to experimental work.

Problem

Research has shown that a mismatch occurs between the teacher’s aim and students’ perception of the laboratory (Woolnough & Allsop, 1985). This leads to students ‘discovering’ the wrong thing and detracts from the effectiveness of laboratory work (Lynch & Ndyetatbara, 1983; Woolnough & Allsop, 1985).

Studies have also shown that students often commence a laboratory activity without knowing the aim of the exercise, the procedure which
they are to carry out, or the conceptual framework surrounding the exercise. During the experiment students often do not understand the steps which they perform, as they follow the procedure in recipe fashion (Moreira, 1980).

Rationale and Significance

Woolnough and Allsop (1985) reported that over 50% of class time is spent engaged in laboratory work, although it is arguable whether the time is of quality and used effectively. If such a large proportion of class time is not to be wasted then techniques should be adopted which will improve the quality of learning from laboratory work.

Implementing the vee-mapping strategy may improve the effectiveness of pre-laboratory and post-laboratory discussions by providing a structure for them. In addition it could help students make links between the outcomes of the practical exercise and the theoretical knowledge upon which the experiment is based.
Purpose and Research Questions

The purpose of this study is to determine whether the effectiveness of laboratory work can be improved by using vee-mapping to structure pre-laboratory and post-laboratory discussion. More specifically, the study addresses the following research questions:

1. Is vee-mapping more effective than traditional post-laboratory discussion techniques for helping students identify the outcomes of an experiment?

2. Is vee-mapping more effective than traditional pre-laboratory discussion techniques for helping students identify the purpose and theoretical concepts of a laboratory activity?

3. What are the difficulties associated with implementing the vee-mapping strategy using a teacher directed approach?
CHAPTER 2: LITERATURE REVIEW

Importance of Laboratory Work

Laboratory work is regarded by science teachers as an important part of the science education process. Teachers consider it important because it is the only strategy which can achieve many of the aims of science education, in particular the development of scientific process skills and apparatus skills. A significant proportion of class time is spent doing practical activities. "It is not uncommon for more than a third of the time of 16-18 year old scientists to be spent on practical work, while most 11-13 year olds will spend well over half of their science lessons doing practical" (Woolnough & Allsop, 1985, p.1,2).

Purposes of Laboratory Work

A number of purposes of laboratory work have been identified and although different sources emphasize different aspects there are elements which are common to all. These are:

Motivational Factors

Many teachers agree that practical work should be done to "interest and motivate students in science lessons" (Woolnough & Allsop, 1985, p.5). Similarly students justify the use of practical work on the grounds of interest and motivation and often enter a science class with the expectation that normally they will be doing a laboratory activity.

Experimental Skills and Techniques

A scientist's work involves 'doing experiments', which requires a set of skills and techniques to be mastered. Observation and measurement skills need to be developed along with techniques for the safe and

**Promote Scientific Thinking**

Students should be encouraged to act like a scientist, and acquire the scientific thinking style. "The intention is to provide practical experiences from which arguments and explanations can be constructed—and in that order: observe, measure, hypothesise." (Lynch, 1987, p.33).

**Reinforce, Support and Develop Theory**

Most teachers agree that this is the fundamental reason for which practical work is used. "Practical work is seen as a means of further reinforcing the understanding of concepts and principles." (Lynch, 1987, p.32). This purpose is based on the belief that 'learning by doing' somehow reinforces learning.

The following sources agree on the following fundamental aims of practical work. (Gould, 1978; Kapuscinski, 1981; Swartz, 1984; Woolnough, 1979; Woolnough & Allsop, 1985).

**Developing Process Skills and Techniques**

Experimental techniques also need to be developed. For example growing plants under controlled conditions and titrations are frequently conducted experiments which students need to be competent at performing. Although this includes aspects of the development of the skills of observation, measurement, estimation and manipulation, it is more than just simple experimental skills.
Being a Problem Solving Scientist

This differs from the promotion of scientific thinking described above. In this context it means, encouraging students to select a problem of scientific interest, getting them to plan and execute the investigation and finally evaluate it. This approach is open ended and divergent where there is no 'right' answer.

Getting a Feel For Phenomena

Students need to appreciate and obtain a feeling for the world they experience. This will come through their first hand experiences, so that knowledge which is built up is placed in a context meaningful to the student. This purpose can be linked to Piaget's theory of intellectual development (Farmer & Farrell, 1980), in that if students are to assimilate and accommodate new information the gap between the new and old cannot be too great. Getting a feel for phenomena helps bridge this gap. An example of this purpose is feeling the air temperature above and around a lighted candle.

Effectiveness of Laboratory Work

At the beginning of secondary school, students bring with them the delight, excitement and eagerness to learn science and perform laboratory experiments. As time progresses, excitement fades and intrinsically motivating experiments to the student are replaced by activities that interest the teacher or fit in with the syllabus. It is also of concern that practical work often holds no interest for girls as they concern themselves with neatly and correctly writing up the experiment. (Woolnough & Allsop, 1985).

Various research has shown that laboratory work promotes the learning of manipulative skills related to working with laboratory
equipment. However, it has been difficult to show that practical work aids the development of anything else (Atkinson & White, 1981; Hofstein & Lunetta, 1982). Experimental skills and techniques other than manipulative skills include making accurate measurements, organising data for analysis and interpretation, recording observations and the higher skills of, for example, planning, executing and interpreting experimental findings. It is easy to assume that over time students will become more competent at handling apparatus through using it, and will master the 'basic skills'. In their studies of the Scottish Education system, Bryce and Robertson (1985, p.4) reported that "In S4 after three years of science teaching, many of the 'basic skills' have not been mastered by a substantial number of pupils". Woolnough and Allsop (1985) also agree that students who have had laboratory experience have not necessarily learned simple skills, and that there needs to be greater emphasis and opportunity placed on the teaching of experimental design skills.

One of the aims of practical work is to allow students to 'act like a scientist' and to develop scientific thinking and problem solving through experiments. There is doubt as to whether the practical work being done by students in schools has much to do with the work of a 'real scientist'. In reality most of the laboratory work in schools is of the 'cookery book' or activity sheet type and does little to develop or reflect the way a scientist works (Woolnough & Allsop, 1985).

There is a growing body of research evidence which suggests that the teaching of concepts through practical work is not an efficient way of transmitting concepts to students. (Tamir, 1989; Woolnough & Allsop, 1985). Hofstein and Lunetta (1982) reported that there is no significant difference between a laboratory teaching method and a discussion group
in terms of student outcomes of achievement of understanding, critical thinking and process skills. Biology students report that more information can be obtained per unit time from a standard lecture approach than from laboratory instruction (Leonard, 1981). The belief that 'hands on' experience reinforces learning, is therefore questionable. Laboratory work is more likely to promote the learning of manipulative skills rather than theoretical understanding.

Practical work is designed to enable the student to discover and understand the theory. The theory which seems so obvious to the teacher, somehow eludes students and they 'discover' the wrong thing (Woolnough & Allsop, 1985). Teachers have certain perceptions of laboratory work as well as expectations of the students completing the laboratory. Students too, have perceptions of laboratory work, though often different from that of the teacher's. In other words there is a mismatch between teachers aims and students perceptions, which leads students to 'discover' the wrong thing (Bryce & Robertson, 1985; Lynch & Ndyetabura, 1983; Woolnough and Allsop, 1985). To overcome this mismatch teachers have developed strategies such as, giving more precise instructions, and asking specific questions to ensure the experiment works and students 'discover' the right thing. This approach has tended to negate at least one of the aims of practical work; that of working like a scientist, being a problem solver.

Teachers spend large amounts of time and effort on practical work. Planning and preparing for a laboratory activity to ensure students complete it, occupies a significant proportion of a teacher's time. The type of student laboratory work performed in the classroom today is not viable in terms of teacher resources and cost of 'materials' (Lynch, 1987; Woolnough & Allsop, 1985).
Moreira (1980, p.447) found that, "in many cases, students perform an experiment without a clear idea about what they are doing or about what lies behind an experiment". Students often work through the laboratory in a recipe type fashion and become engrossed in recording observations so they can transform the data and complete their task as quickly as possible. Research shows that the majority of students have little or no understanding of how their results could be explained. They follow procedures without understanding the reasons for them and the conceptual framework surrounding the laboratory (Johnstone & Wham, 1982; Moreira, 1980; Novak, 1980; Novak & Gowin, 1984; Novak & Ridley, 1988).
Techniques To Improve The Effectiveness of Laboratory Work

Matching Different Types of Practicals to Fulfill the Different Aims.

One of the reasons why laboratory work has not been very effective is because the practical activity has not been matched to the purpose of the laboratory work. This result is partly due to the mismatch between teacher aim and student perceptions of laboratory work. There needs to be different types of laboratory work to fulfill the different purposes. These various types may be described as:

Exercises and Techniques

These are designed to develop scientific process skills. Students need practice at obtaining such skills. The emphasis should be on the process rather than the content of the practical exercises. An example of an exercise in a biology class would be correctly performing the chemical tests for starch and glucose (Woolnough & Allsop, 1985).

Investigations

These are opportunities to give students practice in working like a real problem solving scientist. Investigations are the heart of practical work. They may be as long as one hour or as long a term, may be done individually or in groups, and may be related to the syllabus or independent of it. All investigations require students to start with a problem, analyse it, execute an investigation strategy, collect observations and suggest answers to the problem and evaluate them. Outcomes of such investigational work are positive. Students obtain a sense of satisfaction and accomplishment, as they have produced something by themselves which solves 'their' problem. Quality of
work and meaningfulness are also enhanced (Raghubir, 1979; Woolnough & Allsop, 1985).

Experiences

These are often a short, quick exploratory experiment aimed at getting a ‘feel’ for the phenomena being studied. They lead to students believing phenomena and building up tacit knowledge which can be tapped for later use. An example of such an experience is illustrated by the handling of animals, observing vertebrates and invertebrates and growing crystals.

Pre-laboratory and Post-laboratory Discussion

Pre-laboratory and post-laboratory discussion are distinct stages in the laboratory process. Tamir (1989, p.60) states that one of the reasons for the failure of laboratory work is the “absence or inadequacy of pre-laboratory and post-laboratory experiences and relating them to the relevant theoretical concepts.” Lynch (1987, p.33) also agrees that “the post-lab phase can be a very powerful structural finish to a laboratory session yet surprisingly it is little used.” Pre-laboratory and post-laboratory discussion is not a specific technique for improving laboratory work, but as forementioned it is an integral part of the laboratory session. The above reasons and the fact that pre-laboratory and post-laboratory discussion frequently lack uniform structure and are often specific to the needs of one task, rather than to the linking of concepts together, leads to ineffective laboratory work. It is therefore important to examine the role of pre-laboratory and post-laboratory discussion.

Pre-laboratory discussion prepares students for the laboratory activity. Here the teacher discusses the purpose, equipment and
procedure of the laboratory. Pre-laboratory discussion also explains the relevance of the experiment to the topic being studied and reveals any pre-requisite knowledge (Collette & Chiappetta, 1984; Raghubir, 1979). The difficulty for teachers is to ensure that they do not just focus on the experimental skills required for the laboratory but they also identify the related conceptual knowledge that will be needed to interpret the results from the experiment.

Post-laboratory discussion involves analysis and interpretation of data in terms of the underlying theory, and relates the data to the purpose of the laboratory. It is at this stage that students form links between existing knowledge and the practical exercise, if the post-laboratory is executed properly (Collette & Chiappetta, 1984; Raghubir, 1979). Too frequently it is assumed that students have made the necessary links simply by completing the experiment and obtaining the 'right answer'.

**Vee-Mapping**

Ausubel’s assimilation theory (Novak, 1984), explains how we may learn new knowledge. It describes how learners create new knowledge from that which they already possess. When information is received it is integrated into the existing framework. For information to be learnt it must be presented in a meaningful way. Meaningful learning will result when new concepts are integrated with those already possessed. Teachers implement events which facilitate meaningful learning. In providing such experiences it is important to realise students bring with them an existing framework of knowledge and it is into this that teachers must help students fit new ideas. To facilitate meaningful learning the student must be 'empowered' or be taught to 'learn how to learn' (Brody, 1986; Novak, 1979; Novak & Ridley, 1988).
Based on the assimilation theory of Ausubel, Gowin (1977) developed the epistemological V to help students understand the structure and process of knowledge construction. That is, to illustrate "the relationship between the events or objects we study in science, the conceptual frameworks that guide our work and the resultant claims from our inquiry." (Novak, 1984, p.59). The vee-map is specifically intended for improving laboratory work and is displayed in Figure 1.

![Gowin's Vee Map](image)

**Figure 1  Gowin's Vee Map**

The focus question at the top of the vee is the aim of the laboratory exercise. The vee points to the events and objects, the root of knowledge production which we observe. These two components...
determine the procedure of the exercise. The concepts are those related to the area of study which are linked to relevant principles and theories. Records are transformed into a more retrievable form such as tables and graphs. Knowledge claims are deduced by interpreting the results in terms of the concepts, and are the solution to the focus question (Novak, Gowin & Johansen, 1983; Novak & Gowin, 1984).

The left side of the vee is the conceptual or 'thinking' side and the right is the methodological or 'doing' side. The conceptual framework is built up over time. The right side of the vee displays the knowledge constructions for the current problem. Vee-maps produce on paper the structure of the unit of knowledge being studied, it is a summary of all that is involved in a laboratory exercise.

Vee-maps can be used in a number of ways to improve the effectiveness of laboratory work. Firstly, students can be trained by the teacher to use vee-maps in their laboratory sessions to represent the experiment. Secondly students can 'write up' a laboratory exercise in the form of a vee-map rather than a formal written report. Finally, the vee-mapping strategy can be used by the teacher as a pre-laboratory and post-laboratory discussion structure.

The major application of vee-mapping has been Joseph Novak's (and others) 'Learning How To Learn' project at Cornell University. Novak's principal question was to determine whether seventh and eighth grade students can learn to use concept and vee-mapping strategies. Students were first of all familiarised with the terminology of the vee (focus questions, concepts, knowledge claims, etc) through a series of worksheets. Concept maps were introduced, and at a later stage vee maps, once it was perceived students were ready to apply the concepts
related to the experiment to the interpretation of laboratory events. Once students were taught how to use vee-maps, they applied them to each laboratory exercise to aid in their understanding of the laboratory. The results of this study showed that seventh and eighth graders could acquire an understanding of the vee heuristic and apply it in the science classroom to aid in their interpretation and understanding of experiments (Novak & staff, 1981; Novak & Gowin, et al., 1983). The data did suggest, that "the effective use of the vee heuristic takes time for students to acquire, and it is likely that two or more successive years of work with the vee would be needed for 90% or more of the students to achieve high competence in the use of the vee." (Novak, et al., 1983, p.635).

Another application of the use of vee-mapping was reported by Lehman, Carter & Kahle (1985). This study aimed to help black inner-city, high school students learn biology concepts meaningfully. The instruction was administered over a one semester period to two groups. One group was taught vee-mapping and concept-mapping and the other continued with traditional instruction. The results revealed that there were no apparent differences between experimental and comparison groups (p<0.05).

The study concluded that if the problems that affected the study, such as lack of familiarity with vee-mapping and difficulty of the achievement instruments, could be removed, the vee heuristic could lead to improved learning of concepts. To be successful, also, it would be imperative that the technique be used over a longer period of time and better and longer teacher training implemented.

Both of these studies attempted to improve student learning by
teaching the students to construct vee-maps. An alternative approach, which was not reported in the literature, is for teachers to use the principles of vee-mapping in their teaching strategies. That is, to utilize the vee-map as a technique for them to structure their instruction, particularly the instruction associated with pre-laboratory and post-laboratory discussion.
CHAPTER 3 : METHOD

The general design of this study was a one-group-pretest-posttest, using a class of Year 11 Biology students. Students were pre-tested after traditional instruction, and post-tested after a four stage, five week, treatment programme. Two types of instruments were designed, the first to measure student understandings of a particular laboratory, and the second, student perceptions of pre-laboratory and post-laboratory discussion. The same instruments were used for the both pre-test and post-test.

Subjects

Subjects for this study were an existing class of Year 11 Biology students (n=13) at a West Australian Senior High School. It was not possible to randomly select students or teachers since the experimenter was unable to choose the staff member. However there were no indications that the students were not reasonably representative of typical Year 11 biology students.

Instruments

Two types of instruments were designed and were used for pre- and post-tests. These instruments were intended to gather information about student understandings of a particular laboratory, and their perceptions of the value of pre-laboratory and post-laboratory discussion.
Perceptions of Laboratory Discussions Test (Likert Scale)

This was designed to measure a student's perceptions of the pre-laboratory and post-laboratory discussions. Items in this instrument related to the student's perceptions of various aspects of the laboratory experiments, which were discussed in the pre-laboratory and post-laboratory discussion. These included the purpose, procedure, concepts and knowledge claims of the experiment. The Likert scale instrument is presented in Appendix A. In designing the Likert scale instrument, test parameters were written for each particular aspect of the experiment. Likert scale items were then designed in alignment with each parameter. In Appendix A, the statement alongside each item defines the relevance of a particular aspect of the experiment and hence the reason for including the item in the test. A sample item is presented in Figure 2.

The discussion before the laboratory exercise helped me understand the meaning of each science term and concept.

Figure 2 An example of a Likert scale test item.

Understandings of Laboratory Test (Open Ended Questions).

These items were based on work by Moreira (1980). This instrument required students to answer questions related to the purpose, procedure and outcomes of the laboratory. The answers provided information about students' understanding of the laboratory exercise and were used to better interpret the students' responses to the Likert scale items. For example, if the student responded that the purpose of the experiment was
made clear by the pre-laboratory discussion, and was also able to identify correctly the purpose of the exercise, then the open ended question provided further insights into the Likert scale response. However if a student indicated on the Likert scale, that he or she strongly agreed that they benefited from the pre-laboratory discussion regarding the purpose of the experiment, yet were unable to correctly identify the purpose then the student had still failed to understand the laboratory yet felt confident that they had. The open ended questions instrument is presented in Appendix B. A sample item is shown in Figure 3.

What do you think was the purpose of the experiment?

Figure 3. An example of an open ended test item.

Instrument Development

Draft instruments were critically analysed by two science education experts. The modified instruments were then trialled by gaining responses from 33 first year Biology students enrolled at the Western Australian College of Advanced Education. After completing both tests a group of three students were interviewed to identify any aspects of the test which could have been ambiguous or unclear.

The data from the Likert scale test were analysed using the computer programme LERTAP. The correlations of each item with the overall test were determined from this analysis. Items with a low correlation were
rejected, as a low correlation indicated the item did not fit very well with the other items. The reliability of the final 12 test items was 0.83.

**Design**

A one-group pre-test-post-test design was used for this study where all students in the group were pretested after traditional instruction and posttested after a four-stage, five-week treatment programme. The laboratory exercises on which testing was based were the last laboratories of the traditional and treatment periods and were matched as closely as possible for similar content and procedure. The laboratories were matched so that when testing occurred any changes that resulted were attributable to differing student perceptions, rather than characteristics of the experiments. For example, a laboratory which involves the use of microscopes and another involving performing a chemical test, would produce quite different student outcomes. Both of the chosen exercises required students to handle plant material, make and record observations about a plant, use a microscope and infer information from the results of their experiment.

In addition to the data gathered from students' responses to the test, the teacher was interviewed for his perceptions of the students' attitudes towards vee-mapping and his opinion of the ease of implementation and effectiveness of the strategy. The researcher also observed the second and final lessons of the treatment period to assess the teacher's presentation of the vee-mapping strategy. (See Appendix C)
The chosen experimental design has limitations but more complex designs were difficult to implement without extending the project beyond the scope of this pilot study.

Originally a post-test-only control group design with matched experimental and control groups was to be the proposed method. This design was finally rejected since the limitations of this project would make it difficult to achieve. Two such limitations are, firstly, the difficulty of achieving a sufficiently large enough matched sample of control and experimental groups who could both be taught by the same teacher. The second difficulty was that the alternative of involving more than one school introduced another variable in the form of more teachers and was logistically beyond the extent of this project.

Another design considered was one which involved a test followed by a traditional teaching technique then a test again before a vee-mapping technique followed by a posttest. In this design there would have been a test prior to a four week period of the traditional pre-laboratory and post-laboratory discussion technique. Following this students would have been again tested. The vee-mapping strategy would then have been implemented for a four week period and at the conclusion, the test administered once again. This design was considered as it enabled testing of students' understandings of laboratory exercises, after the four week traditional period, to determine whether any changes in perceptions occurred during this time. This experimental design was rejected for the following reasons. Firstly, the students would have been
in Year eleven biology classes for over twenty weeks. During this time they would have adjusted to the teacher's usual pre-laboratory and post-laboratory discussion strategy. The teacher's strategy and their response to it would have stabilized well before the experimental intervention. A test followed by a further four weeks of the 'traditional' technique, would not produce any major changes in student outcomes due to this stabilization. It is more likely that differences due to changes in the types of laboratory activity may appear, and for this reason the type of experiment was 'matched' for content and procedure for pre-test and post-test. Secondly, this design would not on its own, control the Hawthorne effect which matched pairs could. Finally, exposing students to the identical test three times causes problems as students would begin to recognize items and tend to respond with memory of their previous responses. It would also be difficult to match three laboratory exercises with similar content and procedure and this was considered to be a more likely cause of error.

The chosen design had the advantages that it did not require the need to involve many teachers, hence additional variables, it did not involve manipulating the school curriculum and it was possible to implement in the time frame given.

Procedure.

The teacher of the Year 11 class was taught the vee-mapping strategy and a technique for introducing its structure to pre- and post-laboratory discussion. This was achieved using a short, self teaching package
developed by the author, and is presented in Appendix C. In addition, discussions with the teacher prior to the treatment period, ensured the intent of the programme was understood. This technique for introducing the vee-mapping strategy to a class is an important development of this project since it is intended to avoid the lengthy period required to teach students to develop their own vee-maps.

The self teaching package for teachers outlines the theoretical framework, development and purpose of the vee-map. It also contains a detailed four stage description of the vee-mapping programme for the teacher to follow. The teaching programme was broken into four stages, developing a particular aspect of the vee-map at each stage. The reason for introducing sections of the vee-map gradually, is that Novak (1981) in his 'Learning How to Learn' project, first of all familiarised students with the terminology of the vee- before they used it in its complete form. Novak (1981) also found that a large amount of time was required in order for students to master vee-maps effectively. To avoid this constraint the package was developed to instruct teachers about vee-maps so they could then transfer this information to the students. The teacher structured laboratory discussions around the central elements of the vee.

Immediately prior to the first week of the treatment programme, during the fifth week of term three 1990 the pre-test was administered to the students at the beginning of the Biology class following the previous day's laboratory lesson. The test was administered by the researcher and measured the students' perceptions of the value of
traditional pre-laboratory and post-laboratory discussion techniques.

Over the next five weeks the teacher implemented the vee-mapping strategy into his pre-laboratory and post-laboratory discussion, as detailed in Appendix C. The discussion between the teacher and researcher prior to commencement of the treatment phase, revealed that it would be helpful for students to have a stencil vee-map which they could complete for each laboratory session. The idea was adopted so that for each experiment, the teacher followed the vee-mapping program as outlined in Appendix C and in addition each student filled out a blank vee-map during the pre-laboratory and post-laboratory discussion of the lesson. An example of both forms of blank vee-maps is presented in Appendix D.

At the beginning of each lesson of the treatment phase, a blank vee-map was placed on the overhead projector and an identical copy of this distributed to students. Through teacher directed discussion, a focus question for the experiment was derived which was written onto the vee-map. Students also wrote this focus question onto their map. Secondly, the procedure of the experiment was discussed and explained by the teacher with the class. A skeletal outline of the procedure was then written onto the vee-map and also copied by the students. Students then proceeded with the experiment. After completion of the experiment, students were instructed to transform their data into a more useful form such as a table or graph. The teacher then led a class discussion to generate knowledge claims or conclusions from the activity. The
knowledge claims were then entered onto the students and teacher's vee-maps. At stages 2, 3 and 4 of the teaching programme, pre-requisite concepts were introduced onto the vee-map, during the pre-laboratory discussion. The concepts related to the experiment were discussed, and through questions and explanation to the class, the relevant concepts and their importance were derived by the teacher. After students completed the experiment, knowledge claims were revealed as in stage 1. This discussion linked results and concepts in order to derive knowledge claims. Students were then able to use their vee-maps for future reference.

During lessons two and five of the treatment period the teacher was observed by the researcher. The purpose of this observation was to ensure the presentation matched the planning. At the conclusion of the fifth laboratory lesson, the post-test was administered to the students. The instrument used was the same as that for the pre-test, and measured the students perceptions of the value of vee-mapping as a technique for teachers to structure their pre- and post-laboratory discussion. The effectiveness of the strategy was measured by the gains students made in being able to identify the purpose of the experiment, its outcomes and the theoretical concepts upon which it was based.

Data Analysis.

The purpose of this study was to determine whether the effectiveness of laboratory work could be improved by using vee-mapping to structure pre-laboratory and post-laboratory discussion. Data collected from the
study were used to answer the following questions:

1. Is vee-mapping more effective than traditional post-laboratory discussion techniques for helping students identify the outcomes of an experiment?

2. Is vee-mapping more effective than traditional pre-laboratory discussion techniques for helping students identify the purpose and theoretical concepts of a laboratory activity?

3. What are the difficulties associated with implementing the vee-mapping strategy using a teacher directed approach?

Each of the responses to the 'Perceptions of Laboratory Discussions test' was assigned a mark (1-4) according to the positive or negative weighting of the item.

eg: The purpose of the laboratory exercise

only became clear when I was

actually doing the experiment.

mark  SA  A  D  SD

A response with a low score indicated a high, positive perception for the item.

Student data for the 12 items were entered into the computer programme LERTAP. LERTAP provided a profile of each subject which included the student's summated score. It also provided data about an individual item's percentage of responses, correlation to total test score, mean and standard deviation. In addition, for the overall test and subtests, the programme provided standard deviation and reliability estimates.
The summated scores for individuals were used as the basis for testing for changes between the pre-test and post-test. After these data had been entered, t-tests were conducted on the differences between summated scores, using the computer programmed MINITAB to test for any changes.

Question one of the open ended test, relating to the purpose of the experiment, was marked on a four point scale. The students' answers to this question were used to provide further insight into student responses to the first three Likert scale items.

Experimental outcomes of the experiment were examined in Question two of the open ended test. Student answers to this question were categorized into the main things students believed they had learnt.

Student responses to Question 3, relating to the major science concepts, were expressed as a proportion of the correct list of concepts. Trends which emerged between pre-test and post-test scores were then interpreted.

**Assumptions and Limitations**

Apart from the assumptions and limitations which were discussed under design there are further reasons why results from this study should not be generalized to any broader population.
A one-group pretest-posttest design was selected, it being the most appropriate for the study. The following extraneous variables may have jeopardized internal validity in this design (Gay, 1987).

(a) History - This refers to any event not part of the treatment which may affect the performance of students. To some extent this was controlled by the short period of treatment and by ensuring that the two laboratory exercises after which testing occurred were similar.

(b) Maturation - In a five week period physical or mental changes other than those associated with the treatment would be minimal.

(c) Testing - The tests measured student perceptions of the experiment rather than the understandings of the laboratory activity. Hence students should not have improved on the second test because of learning from the test itself, but because of the effect of the different strategy.

(d) Pretest-treatment interaction - students may react differently to a treatment because they have been pretested. However the test itself was not an unusual structure and its effect in this respect may have been limited.

For these reasons and the small sample size it is difficult to generalize the results from this study to other students or to other schools. However a major purpose of this project was to identify logistical and implementation problems when vee-maps are used by a teacher to structure the pre-laboratory and post-laboratory discussions. In this sense the research should be regarded as a pilot project as this was a new approach, to the use of vee-mapping. The technique does not
appear to have been used before as a way to structure the teacher's presentation of pre-laboratory and post-laboratory discussions. The study intended to identify teacher implementation problems as well as the potential for student gains.
CHAPTER 4: RESULTS

The results of this study are presented and described in this chapter. Tables 1, 2 and 3 display the students' summated individual scores, students' ability to identify concepts and identification of experiment outcome, respectively. The item means of the Perceptions of Laboratory Discussions Test as well as the number of students who were able to identify the purpose of the experiment are presented in tables 4, 5 and 6. Results of the teachers perception of the vee-mapping strategy are displayed in the form of anecdotal records. The significance and implications of the results are discussed in chapter 5.

Student Summated Individual Scores

Table 1 displays the result of the one tailed t-test calculated on the difference between summated individual scores. These scores were gained by assigning a value to the responses of, 1 for strongly agree through to 4 for strongly disagree, for positively weighted items, and 4 for strongly disagree through to 1, for negatively weighted items. The total for all twelve items provided the summated score in Table 1.
### Table 1
Perceptions of Laboratory Discussions Test Scores- Pre-test & Post-test

<table>
<thead>
<tr>
<th>Student</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33</td>
<td>23</td>
<td>-10&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>23</td>
<td>17</td>
<td>-6</td>
</tr>
<tr>
<td>3</td>
<td>23</td>
<td>22</td>
<td>-1</td>
</tr>
<tr>
<td>4</td>
<td>26</td>
<td>24</td>
<td>-2</td>
</tr>
<tr>
<td>5</td>
<td>24</td>
<td>26</td>
<td>+2</td>
</tr>
<tr>
<td>6</td>
<td>28</td>
<td>26</td>
<td>-2</td>
</tr>
<tr>
<td>7</td>
<td>26</td>
<td>24</td>
<td>-2</td>
</tr>
<tr>
<td>8</td>
<td>28</td>
<td>24</td>
<td>-4</td>
</tr>
<tr>
<td>9</td>
<td>22</td>
<td>19</td>
<td>-3</td>
</tr>
<tr>
<td>10</td>
<td>24</td>
<td>21</td>
<td>-3</td>
</tr>
<tr>
<td>11</td>
<td>28</td>
<td>25</td>
<td>-3</td>
</tr>
<tr>
<td>12</td>
<td>30</td>
<td>17</td>
<td>-13</td>
</tr>
<tr>
<td>13</td>
<td>27</td>
<td>26</td>
<td>-1</td>
</tr>
</tbody>
</table>

- **mean** 26.31 22.62<sup>**</sup> -3.69
- **S.D.** 3.15 3.23

**Note.**
- A lower score indicates that students have a higher positive perception
- **one tailed t-test significant difference p<0.01**
The result of this test $t(12)=3.36, p<.01$ shows that there was a significant positive gain in students' perceptions of the value of pre-laboratory and post-laboratory discussion, after the vee-mapping programme.

**Concept Identification**

Table 2 presents data on the student's ability to identify the major concepts related to the experiment. Students are listed and the proportion of concepts each correctly identified for the pre-test and post-test is displayed.

Table 2 indicates that after the pre-test only six of the subjects could identify more than half of the major concepts. After the post-test though, eight of the subjects were able to identify all of the major concepts correctly, while of the remaining five students, four were able to identify two of the three major concepts associated with the experiment.
Table 2

Proportion of Major Concepts Identified by Student's

<table>
<thead>
<tr>
<th>Student</th>
<th>Pre-test(/1)</th>
<th>Post-test(/1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>2</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>0.25</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>8</td>
<td>0.25</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>10</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>11</td>
<td>0.25</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>0.25</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>0.25</td>
<td>0.3</td>
</tr>
</tbody>
</table>
The Wilcoxon Signed-Rank test when applied to this data, showed that at the \( p < 0.05 \) level, there was a difference between the pre-test and post-test data on students' ability to identify the concepts of an experiment.

**Identification of Experiment Outcomes**

Table 3 displays information which describes the outcomes students perceived they had learnt from each of the pre-test and post-test experiments. Student responses were categorized into three groups which were:

+ identified main idea of the experiment
+ identified a narrower aspect of the experiment rather than the broader outcome
+ unable to identify the major conceptual outcome of the experiment.

The numbers of students within each category for the pre-test and post-test are presented in Table 3.

<table>
<thead>
<tr>
<th>Number of Students' Able to Describe Experimental Outcome (N=13)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Number of students</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Pre-test</strong></td>
</tr>
<tr>
<td>-------------------------------------------------------------</td>
</tr>
<tr>
<td>Main idea</td>
</tr>
<tr>
<td>Narrow aspect</td>
</tr>
<tr>
<td>Incorrect</td>
</tr>
</tbody>
</table>
The results from Table 3 indicate that there would appear to be no difference between pre-test and post-test data where students were asked to identify the experimental outcomes. A Chi-squared test applied to these results confirmed the implication that there was no significant difference between pre-test and post-test data at the .05 level of confidence (χ²=.202).

**Item Means of Perceptions of Laboratory Discussions Test**

The purpose of an experiment is revealed during the pre-laboratory discussion. The intent of research question two was to determine whether vee-mapping is more effective than traditional pre-laboratory discussion techniques when helping students to identify the purpose of a laboratory activity.

Tables 4, 5 and 6 display data pertinent to research question 2. Table 4 presents the mean scores gained by all students on each of the items 1 to 6 from the Perceptions of Laboratory Discussions Test when given as a pre-test and then as a post-test. Only the means of items 1 to 6 are presented as these are the items which relate to pre-laboratory discussion and thus the purpose of the experiment.

As the research question focused on the purpose of the laboratory, the data emerged from an analyses of items 1 to 6. That is, only those items concerned with the pre-laboratory discussion. Since items 7 to 12 refer only to the post-laboratory discussion the mean scores from these were analysed in an attempt to better interpret the other observed changes. These data are presented in Table 5.
Table 4

Student Mean Scores For Items 1 to 6 (Pre-Lab) on Perceptions of Laboratory Discussions Test

<table>
<thead>
<tr>
<th>Item</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.54</td>
<td>2.08</td>
<td>-.46&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>2.08</td>
<td>1.92</td>
<td>-.15</td>
</tr>
<tr>
<td>3</td>
<td>2.15</td>
<td>1.85</td>
<td>-.31</td>
</tr>
<tr>
<td>4</td>
<td>2.38</td>
<td>1.69</td>
<td>-.69</td>
</tr>
<tr>
<td>5</td>
<td>2.23</td>
<td>2.08</td>
<td>-.15</td>
</tr>
<tr>
<td>6</td>
<td>2.46</td>
<td>2.46</td>
<td>0</td>
</tr>
<tr>
<td>mean</td>
<td>2.31</td>
<td>2.01**</td>
<td>-.29</td>
</tr>
<tr>
<td>S.D</td>
<td>.18</td>
<td>.26</td>
<td>-.25</td>
</tr>
</tbody>
</table>

Note.

<sup>a</sup> A lower score means that students have improved their ability to define the purpose of the laboratory.

** one tailed t-test significant difference p<.05
Table 5

Student Mean Scores For Items 7 to 12 (Post-Lab) on Perceptions of Laboratory Discussions Test.

<table>
<thead>
<tr>
<th>Item</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>2.15</td>
<td>1.62</td>
<td>-.54&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>8</td>
<td>2.0</td>
<td>2.0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>2.0</td>
<td>1.77</td>
<td>-.23</td>
</tr>
<tr>
<td>10</td>
<td>1.93</td>
<td>1.69</td>
<td>-.24</td>
</tr>
<tr>
<td>11</td>
<td>1.92</td>
<td>1.77</td>
<td>-.15</td>
</tr>
<tr>
<td>12</td>
<td>2.15</td>
<td>1.69</td>
<td>-.46</td>
</tr>
</tbody>
</table>

| mean | 2.03 | 1.76 ** | -.27 |

| S.D  | .10  | .13     | -.19 |

Note.

<sup>a</sup> A lower score means that students have gained more from the post-laboratory discussion.

** one tailed t-test significant difference P<.05
Tables 4 and 5 show that there is a general decrease in item means. When t-tests are applied to these data they show that there is a difference between the summated means. This indicates that after the vee-mapping strategy students believed they had gained more value from pre-laboratory and post-laboratory discussions, than they had from traditional methods.

Identification of Purpose

Table 6 presents information related to the purpose of the experiment. It combines student perceptions about whether the pre-laboratory helped them to identify the purpose of the experiment (data from the Perception of Laboratory Discussions test) with whether they actually identified the purpose (data from the open-ended test). Students were categorized as:

+ category 1- claimed the pre-laboratory helped identify purpose AND was able to correctly identify purpose
+ category 2- claimed the pre-laboratory helped identify purpose AND was not able to correctly identify purpose
+ category 3- claimed the pre-laboratory did not help identify purpose BUT was able to correctly identify purpose
+ category 4- claimed the pre-laboratory did not help identify purpose AND was not able to identify purpose.

All of the students (except one) on the post-test said the pre-laboratory discussion helped them identify the purpose of the experiment, compared with 10 on the pre-test. Eight students were able to correctly identify the purpose of the experiment for the post-test, and nine for the pre-test. A Chi-squared test applied to these results indicates that there
### Table 6

Number of Students’ Able to Identify Purpose of Experiment

<table>
<thead>
<tr>
<th>Category</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

**Note.**  
See page for description of categories
was no significant difference between pre-test and post-test data 
\[ \chi^2(7, N=13)=2.95, p<.05. \]

Teacher's Perceptions of Vee-Mapping

Anecdotal records were collected to answer Research question 3. This information was gathered by interviewing the teacher about his perceptions of the vee-mapping strategy and from two occasions when the researcher observed the laboratory lessons. This information is summarized under three sub-headings; Impressions of vee-map, ease of implementation and overall effectiveness of vee-map.

Impressions of Vee-map. The teacher commented that the vee-map was a useful summary tool for laboratory lessons, as it reduced clutter, there were no questions or minor procedural points displayed, only the major aspects of the experiment. He also found that introducing the concepts was useful, especially when referring to the concepts in the post-laboratory discussion.

The teacher also remarked that the term 'knowledge claims' was confusing to students', and took them some time to adjust to, as the term was not recognizable to students'. He suggested that a term with which students' are already familiar be used, such as conclusions. Further, the teacher found that there was not enough space to write all information onto the vee-map, especially the knowledge claims. He suggested that the results be recorded on the back of the vee-map, so a summary could appear on the front.
Ease of Implementation. The teacher found the vee-map easy to implement. The researcher also observed that the teacher carried out the pre-laboratory and post-laboratory discussions using the vee-map with ease and that they did not occupy any more time than usual. The teacher also commented that students took a while to adjust to the use of the vee-map, but once this had been overcome, there were no problems. Further, the teacher remarked that as soon as the blank vee-map was distributed to students they commenced filling it in. This aspect was also observed by the researcher and students seemed to treat the vee-map as a normal part of their laboratory lessons.

Overall Effectiveness of Vee-mapping. The teacher commented that he believed that the vee-map improved the overall effectiveness of laboratory lessons. He said it made students consider the importance of each laboratory, select an appropriate focus question and that it emphasized the conclusion of the experiment. This was also observed by the researcher as the teacher emphasized deriving a focus question, highlighting the procedure and concepts and linking the results of the experiment to the concepts.
CHAPTER 5: DISCUSSION

This chapter considers the implications of the data, and the possible generalization of the conclusions to other populations.

Student Summated Individual Scores

Table 1 displays student raw scores of the 'Perceptions of Laboratory Discussions Test', the score differences, means and standard deviations for the pre-test and post-test. A one tailed t-test applied to this data was shown to be significant at the \( p < 0.01 \) level. This result implies that the vee-mapping strategy produced an increased positive effect on students' perceptions of the pre-laboratory and post-laboratory discussion. That is, after the treatment phase students perceived they had gained more worth from the purpose, procedure, concepts and knowledge claims of each experiment, due to the structure of the pre-laboratory and post-laboratory discussion. This result supports the work by Novak & Gowin et al. (1983), where students' were taught to use vee-maps. Although the current study differs in that the teacher used the vee-mapping strategy, the results are similar, as in both cases students believed they had benefited in their understanding of laboratory experiments, due to vee-mapping procedures. The major benefit in this current strategy was the dramatic decrease in the time required to obtain such gains.

Concept Identification

Data concerning students' ability to identify the major concepts associated with an experiment showed that after the treatment phase students were able to identify a greater proportion of the pre-requisite concepts correctly. The ability to identify and understand concepts related to an activity is the basis for comprehending the experimental
knowledge outcomes discussed during the pre-laboratory discussion of the treatment period. The results thus suggest that the vee-mapping strategy increases students' awareness of concepts associated with an experiment. Novak, et al. (1981) have shown that when students increase their awareness of experimental concepts they also increase their understanding of the experiment.

Inspection of student mean scores for the pre-laboratory discussion of the Perceptions of Laboratory Discussions Test, (Table 4) suggests that students also believed they had gained more value from the pre-laboratory discussion and thus the identification of concepts for an experiment, after the post-test. Thus both their perception of their ability and their actual ability to define the pre-requisite concepts had improved.

Identification of Experiment Outcomes

Information related to the ability of students to identify the major experimental outcomes is contained in Table 3. Analysis of this data showed there was no significant difference between student pre-test and post-test data. This result suggests that the vee-mapping strategy did not assist students in identifying the experimental outcome of the activity. One possible reason for this result may have arisen from the structuring of the question on the open ended test. This may have been unclear or ambiguous to students for, even though this aspect was considered by trialling the instrument with tertiary students, the final sample was younger than the trial group. An indicator of the confusion which may have arisen was displayed by a student who responded;

Q- What did you feel you learnt from the experiment?
A- I learnt that when germination occurs the actual stuff that gets dropped on the pollen of a flower grows a tube downward to fertilize
the egg. This student wrote down what they felt they learnt, but in fact the student focused on a minor outcome of the experiment.

A second possible reason for the lack of improvement may have resulted because discussion of experimental outcomes occurred in the post-laboratory phase of the lessons. The teacher's traditional post-laboratory discussion may have already been effective so that the vee-mapping technique did not have any effect on improving a student's ability to identify the experimental outcome. The traditional technique and vee-mapping strategy are very similar in their post-laboratory discussion approach, as they both discuss the outcomes of the experiment in relation to the purpose. However, the two strategies differ markedly in their approach to pre-laboratory discussion, as vee-mapping develops the focus question, highlights the procedure and introduces the associated concepts, whereas the traditional technique does not. Rather, it briefly mentions the purpose and procedure of an experiment. This finding is further supported by inspection of Tables 4 and 5, which show that students' mean gain was slightly higher from the pre-laboratory discussion than from the post-laboratory discussion.

Although the ability of the students to identify the major outcomes did not improve they believed that the vee-mapping technique did help them. This was shown by Table 2.

A further possible explanation for the lack of difference is that, the small sample size limited the result from showing any significant differences between the pre-test and post-test data.
The intent of Research question 2 was to determine whether vee-mapping is more effective than traditional pre-laboratory discussion techniques when helping students to identify the purpose of a laboratory activity. Data related to the pre-laboratory discussion for pre-test and post-test were analysed. To provide further insight and explanation of the pre-laboratory data, the post-laboratory discussion data were also analysed.

Table 5 displays information related to means of items 7 to 12 of the 'Perceptions of Laboratory Discussions Test', that is the post-laboratory discussion. Analysis of this data indicates there is a significant difference between pre-test and post-test scores. This implies that students gained more from the post-laboratory discussion after the vee-mapping strategy than they had after a traditional approach.

Identification of Purpose

Information about students' perceptions of the purpose of an experiment was compared with the students' actual ability to identify the purpose of the experiment. Analyses of these data (Table 6) indicated no significant differences between pre-test and post-test comparisons. Students believed they had gained more from the pre-laboratory and post-laboratory discussions and purpose of the experiment, after the vee-mapping strategy. However, in reality students were not able to identify the purpose of an experiment any better after the vee-mapping strategy. One possible explanation for the lack of difference is that, the small sample size limited this result from showing any significant differences between the pre-test and post-test data.
Teacher's Perceptions of Vee-Mapping

Inspection of the anecdotal records collected about the teacher's perceptions of the vee-mapping strategy suggest that the teacher found the vee-map to be a useful summary tool for each laboratory lesson. Further, he found the vee-mapping strategy easy to implement into the pre-laboratory and post-laboratory discussions, and that once students became adjusted to the strategy, it became a normal part of their laboratory lesson routine. Overall the teacher perceived that the vee-map improved laboratory effectiveness as it made students consider the importance of each laboratory and emphasized the conclusion of the experiment.

Students' Attitude

Students thought they had gained more value from both the pre-laboratory and post-laboratory discussions after the vee-mapping strategy. Inspection of the mean of the differences between the pre-test and post-test means for the 12 items shows that there was a greater mean difference for the pre-laboratory discussion (.29), than for the post-laboratory discussion (.27).

Although students perceived they had gained more value from the pre-laboratory and post-laboratory discussions after the vee-mapping strategy, this may not be the case. Data indicated that students did not show any significant increase after the post-test in their ability to identify the purpose of an experiment or to identify major experimental outcomes. Examination of the open ended test provided further insight into this observation. Question 4 on the open ended test stated; Did the pre-lab (or post-lab) discussion help you in any other way? Students' responses to this question on the pre-test mainly concentrated on the procedural aspect of the experiment. However on
the post-test a number of interesting students comments were noted;
- the discussion finalized the concepts etc
- it helped me to understand the purpose and results of the experiment (broadened my understanding)
- the pre- and post-lab discussions helped to clarify what the experiment was about and justify the results
- post-lab discussion helped me to understand differentiation in the pea seedling and therefore other organisms
- it helps me understand the relevance of the experiment to other things occurring in the world and around me
- the pre-lab helped me because it was an indication to what I should be looking for, with the experiment; the post-lab helped to clarify some of the conclusions I had made and explain some questions I didn't understand
- helped me to understand the concepts of growth and development

These student comments further support that students perceived greater gains from the pre-laboratory and post-laboratory discussions after the vee-mapping strategy and supports the work by Novak on vee-mapping. However a possible reason why the data did not provide a significant difference in the statistical testing procedure may have been due to the small sample size.

Conclusions

In summary, this study has shown that vee-mapping can be successfully and easily implemented into the pre-laboratory and post-laboratory discussions of laboratory lessons, by the teacher. Students perceived they had gained more value from the pre-laboratory and post-laboratory discussions after the vee-mapping strategy. In reality students did not show improvement in all aspects of laboratory outcomes. This may have been due to the small sample size. However,
regardless of whether there was a significant gain, the students' attitude towards laboratory discussions was more positive as was evidenced by their perceptions and the teacher's comments.
CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

This chapter summarizes the main findings of the study and recommendations for teachers using the vee-mapping strategy. Some suggestions are made for further research on the teacher directed approach to vee-mapping.

Study Findings

The success of the vee-mapping strategy as a pre-laboratory and post-laboratory discussion strategy, as revealed by a Perceptions of Laboratory Discussions Test and Understandings of Laboratory Discussions Test, has been presented in Chapter 5. These outcomes are summarized here as a sequence of points.

* Students believed they had gained more from the pre-laboratory and post-laboratory discussions and purpose of the experiment, after the vee-mapping strategy. However students could not identify the purpose of an experiment any better after the vee-mapping technique than after traditional teaching strategies.

* Students perceived the vee-mapping strategy helped them to identify the major outcome of an experiment, yet after the treatment phase they could not identify the major outcome any better than after a traditional laboratory discussion approach.

* The vee-mapping technique was effective at improving the students' ability to identify the pre-requisite concepts related to an experiment.
* Students believed they had gained more from both the pre-laboratory and post-laboratory discussions after the vee-mapping strategy. There was a greater gain in perception of the value of these discussions for the pre-laboratory discussion than for the post-laboratory discussion.

* The vee-mapping strategy can be successfully and easily implemented into the pre-laboratory and post-laboratory discussions of a laboratory activity by the teacher using a four stage, structured implementation package.

* Students' attitudes towards laboratory discussions were more positive after the vee-mapping strategy than after a traditional approach.

Limitations of The Study

The major limitation of this study was the one-group pretest-posttest design which was used. The design involved one teacher and one class of students. This meant there was no control group with which to compare the vee-mapping strategy. The one-group pretest-posttest design was selected as it was the most logistically feasible given the available time period to conduct the study.

The experimental design applied over a short five week time period meant that some of the data which were collected did not show students gained in understanding of the laboratory, any more than traditional instruction, after the vee-mapping strategy. This restricted time for the implementation of the strategy may have limited the observable gains.
The selected design used only one class of students, which thus limited the sample size (N=13). This made it difficult to obtain substantial results when applying statistical test of significance to the data.

**Recommendations for Teachers and for Further Research**

The following recommendations are derived from analysis of the related science education literature reviewed in Chapter 2, and an analysis of the results discussed in Chapter 5.

* Vee-maps can be quite easily and successfully implemented by the teacher into the pre-laboratory and post-laboratory discussions, in a relatively short period of time, without occupying extra classroom time. The self-teaching package in Appendix C could be used by teachers as a guide to introducing vee-maps to students.

* Some of the terms on the vee-map, for example, knowledge claims, are unfamiliar to students. When teachers implement the vee-map they should take considerable time to develop each of the aspects on the vee-map. This will ensure that students fully understand what each term means, so that they obtain maximum benefits from the use of vee-mapping. The term 'conclusion' as a substitute for knowledge claims is not recommended. It has connotations from traditional methods which are not appropriate to the vee-mapping interpretation of the term.

* Students developed a more positive attitude towards laboratory work over a short four week time period although they did not show an increase in identifying some aspects of an
experiment. A gain in positive attitude over a short period of time implies that there is potential for improved learning over a longer time. Therefore there is a strong basis to suggest that further research should be conducted into vee-mapping, but on a larger sample and for a longer time period, to reveal if gains in learning occur. It would be particularly interesting to see whether significant gains are made over a slightly longer teaching period of the vee-mapping strategy. Another possible research method could be to introduce the vee-mapping strategy for four weeks and post-test students. A further four weeks after the post-test, students could be again tested to see if they retain information about a laboratory.
REFERENCES


Brody, M. J. (1986). *Translating research reports into educational materials or how to take a neat piece of research and turn it into a curriculum*. Unpublished manuscript.


APPENDIX A

Perceptions of Laboratory Discussions Test

Instructions to the Student: These questions relate to the laboratory discussion before your last experiment. You are asked to respond to each of the statements below by circling the response which matches your feelings, where:

SA - strongly agree
A - agree
D - disagree
SD - strongly disagree

Please read and think about each question carefully before responding.

The purpose of the laboratory exercise only became clear when I was actually doing the experiment. SA A D SD

I did NOT need the pre-lab discussion to help clarify the purpose of the experiment. SA A D SD

The purpose of the laboratory exercise was NOT made clear by the pre-lab discussion. SA A D SD

It was the discussion before the laboratory exercise which helped me to understand what I was doing during the experiment. SA A D SD

Being aware of the major science terms and concepts helps me in understanding the results of the experiment. SA A D SD

The discussion before the laboratory exercise helped me understand the meaning of each science term and concept. SA A D SD
**Instructions to the Student:** These questions relate to the laboratory discussion after your last experiment. Answer each question by circling the response which matches your feelings, as before.

Please read and think about each question carefully before responding.

The post-lab discussion helped me to relate the science terms and concepts to the results which I collected. SA A D SD

The discussion following the laboratory exercise did NOT reveal the outcomes of the experiment. SA A D SD

The post-lab discussion helped me to draw a conclusion about the experiment. SA A D SD

The post-lab discussion helped me understand the results of the experiment. SA A D SD

After the discussion following the experiment I had not learnt any 'new' science. SA A D SD

Even after the post-lab discussion I did not feel I had learnt much from the experiment. SA A D SD
APPENDIX B

Understanding of Laboratory Test

Instructions to the Student: The following questions relate to the last laboratory activity which you did. Write an answer to each of the questions in the space provided.

Question 1

What do you think was the purpose of the experiment?

Question 2

What did you feel you learnt from the experiment?

Question 3

Write down key science terms/concepts which you believe were related to the experiment.

Question 4

Did the pre-lab (or post-lab) discussion help you in any other way? Yes/No. If Yes, please explain.
This year I am undertaking study for my Bachelor of Education with Honours in the Science Education area. My thesis is on the effect of vee-mapping on student learning outcomes from Science laboratory lessons.

It is widely accepted in Science Education that laboratory work has an important role in the learning of science because great emphasis is placed upon it in schools. A considerable amount of class time is spent doing laboratory work, so the question is raised as to how much value laboratory work is to student learning.

The literature shows that teachers have been concerned that in many situations, students commence a laboratory activity with perceptions of the aim and procedures which don't match the teacher's intent. Further, they have little understanding that experimentation is a way of forming knowledge.

One technique that has evolved to help solve these difficulties is the use of pre-laboratory (pre-lab) and post-laboratory (post-lab) discussion. If used correctly this technique will make laboratory work more meaningful to students by focussing their attention on the aim of the laboratory, and linking new knowledge to existing schemata and help them to learn more effectively.

Pre-lab discussion is a teacher led discussion about the procedure of
the laboratory, special handling of apparatus that students need to be aware of and answering of any questions about related concepts which are preliminary to successfully understanding the laboratory class. That is, discussion of the underlying theory.

Post-lab discussion, also teacher led, involves an overall tying together of the laboratory session. It includes linking prior knowledge to new knowledge obtained during the laboratory, through teacher questioning. Post-lab discussion though, is an important part of the laboratory session, as it is highly likely that during this time students form links, recognize the relevance of the laboratory exercise and so 'learn' new knowledge.

THE VEE-HEURISTIC

Currently teachers use various forms of pre-lab and post-lab discussion. What I am proposing in my thesis is not to dispense with these sessions but to modify their approach by implementing a form of pre-lab and post-lab discussion which has a specific structure. This structure will achieve a number of things. It will: (i) ensure students learn more effectively from the laboratory exercise by increasing the chances of linkage occurring between theoretical knowledge and learning outcomes gained from the exercise; (ii) make it easier for teachers to identify essential prior knowledge students require before commencing the exercise.

The structure I propose to use is Gowin's Vee-heuristic. If used correctly and efficiently the vee will not occupy any more class time than present pre-lab and post-lab discussion techniques, but may increase the effectiveness of these sessions.
The vee-heuristic was developed as a device to help students understand the structure and process of knowledge construction, and is especially intended for laboratory work. Below is an outline of a vee-diagram.

<table>
<thead>
<tr>
<th>Conceptual</th>
<th>Methodological</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Knowledge Claims</td>
</tr>
<tr>
<td>Theory</td>
<td>Question</td>
</tr>
<tr>
<td>Principles</td>
<td>Transformations</td>
</tr>
<tr>
<td>Concepts</td>
<td>Records</td>
</tr>
<tr>
<td>Object/Event</td>
<td></td>
</tr>
</tbody>
</table>

The focus question(s) is the aim of the laboratory exercise. The vee points to the events and objects, the root of knowledge production which we observe. They are the general procedure of the laboratory activity. The concepts are those related to the area of study which are linked to relevant principles and theories. Records are transformed into a more retrievable form such as tables and graphs. From the transformation, knowledge claims are made, which are the solution to the focus question.

The left side of the vee is the conceptual or 'thinking' side and the right side is the methodological or 'doing' side. The conceptual framework is built up over time while the right side displays the constructions for the current problem. The vee-map, thus helps
students see the interplay between conceptions and practical experiences.

Vee-maps produce on paper the structure of the unit of knowledge being studied. Below is an example of a vee-map for a science experiment.

### Vee-Map Example

- **Conceptual**
  - Theory: Kinetic Theory
  - Concepts:
    - Ice, water, boiling
    - Heat, bubble temperature, thermometer, phase change, states of matter.

- **What happens to ice when heat is added?**

- **Methodological**
  - Knowledge Claims:
    - Ice remains at the same temperature when melting.
  - Transformation:
    - Temp about 0°C, ice and water etc.

- **Ice water subjected to heat**

Rather than teach students how to construct and use vee-maps (which is a time consuming and complex task), I am proposing to teach you the teacher how to use and implement vee-mapping into your pre-lab and post-lab class discussions, in order to improve these techniques and make them more effective. In this way normal student learning patterns will not be disrupted, nor should it impinge on your class time, as you already practise these strategies in some form.

**THE VEE-MAPPING PROGRAMME**

This package contains a detailed 4 week program, on implementation of the vee-map into pre-lab and post-lab discussions. It has been
designed in a way which makes it simple for you to implement. The package has been broken down into 4 stages (1 each week) so that at a given time you will know exactly what aspect of the vee-map you should be emphasizing.

Before the vee-mapping technique is introduced, a pre-test will be administered to students to determine learning outcomes of laboratory work using your usual form of pre-lab and post-lab discussion. At the conclusion of the 4 week treatment program, a post-test will be administered to determine student learning outcomes of the vee-maping pre-lab and post-lab discussion strategy.

The remainder of this package outlines the 4 week program of implementation and includes any teaching aids required.

IMPLEMENTATION OF THE VEE-MAPPING PROGRAMME

Pre-test

At the end of the week prior to commencing the treatment program, I would ask that I administer the pre-test. I will distribute the test after the laboratory session either at the conclusion of the laboratory or in the next class and instruct students to complete ALL questions.

STAGE 1 (WEEK 1)

Pre-lab

Explain to students that over the next 4 weeks laboratory classes will be conducted using a slightly different format. A picture of the vee should then be shown to the class on overhead transparency (attached).
Introduce the vee-map to students and explain that through teacher led discussion it will be filled in during the lesson, and that when it is complete it will present an overall outline of the laboratory.

At the beginning of each lesson place the stencil vee on the overhead projector or draw one on the black/whiteboard. As you can see it is a simplified version of Gowin's vee.

In upper school science, teachers constantly tell students to read the laboratory exercise they are going to do, before coming to the class, but in most cases only a minority of students actually complete this small and simple task. Question the class on the purpose of the laboratory lesson. Fill in this purpose on the vee at position 1, in the form of a question to be answered. Now all students can see, by looking at the vee, what they are trying to find out during the laboratory exercise.

At this point any preliminary questions which need to be asked concerning prior learning to this laboratory exercise can be asked.

Question students on how they are going to answer the focus question, that is, the procedure to carry out. Fill in this on the vee at position 2. This should be kept very brief. A diagram may help. The basic overall set up of the experiment is adequate. eg: saliva and starch suspension (cool and heated). Here any particular points about the procedure which need to be further explained or especially noted can be revealed to students.

Post-lab

After students have completed the experiment and results are collected, the teacher or a student can enter them on the vee at position 3.
From the transformation, class discussion should lead to knowledge claims (conclusions) being made, which the teacher enters at 4 on the vee. Discussion through questioning and explanation should then conclude the lesson by linking 1, 2 and 4.

The basis of stage 1 is to introduce students to the vee and familiarize them with it, so they can see it as being a part of every laboratory session. Entering the focus question, events, transformation and knowledge claims should be nothing new, as students are usually required to write up a formal report. Vee-maps are a different form of this.

STAGE 2 (WEEK 2)

Pre-lab

Concepts are the next part or the vee which need to be introduced. At the beginning of the first laboratory class in week 2, present a completed example vee to the class as follows. On the overhead projector display a completed vee of one of the laboratory classes from week 1. Write onto this vee at position 5 (which is at present blank), the concepts associated with this laboratory exercise. Explain that concepts are terms that link two or more ideas, and they are necessary to understand the laboratory lesson. The concepts you have listed should be familiar to students as they would have already used them in post-lab discussion of the laboratory exercise. Writing concepts on the vee simply allows students to identify those concepts which are important and relevant to the laboratory lesson and hence their understanding. Examine each of the concepts you have listed and explain how they are relevant to the laboratory exercise.

Now continue with today’s exercise. That is, develop a vee-map for
the next laboratory class.

- focus question and event/object: same as stage 1 but, really emphasize that students should read the laboratory exercise before coming to class. When filling out position 1 and 2 on the vee ask a variety of different students to contribute.
- Write onto the vee at position 5, concepts relevant to the day’s laboratory exercise. Briefly explain how each concept is related to the exercise.

Post-lab

- transformations and knowledge claims: As for stage 1 but link 1, 2, 4 and 5. That is, conclude the discussion through questioning and explanation during which you should link the purpose, event, knowledge claims and concepts.

  eg: For the example of heating ice water as previously displayed— Use a pointer to identify various sections on the vee during discussion. Discussion could be along the lines of: “Our purpose was to determine what happens to the temperature of ice water when we added heat. To do this we observed ice water subjected to heat. To understand our observations we needed to first of all understand what was meant when we use each of these terms: what ice, water, boiling, heat, thermometer and bubble temperature meant. This allowed us to make our knowledge claims that... etc”

STAGES 3 AND 4 (WEEKS 3 AND 4)

Pre-lab

- focus question and events: as for stages 1 and 2
- concepts: Ask class for associated concepts to the laboratory exercise. By this stage they should be familiar with identifying concepts. As students present a concept discuss its relevance and write it on the vee. Explain to students that recognizing and understanding
these concepts is the key to understanding the laboratory.

For week 4, ask students to prepare a list of concepts before the laboratory, and to bring it to class so that they will have previously thought about them prior to the exercise. Concepts are the basis to understanding the laboratory, so it is important they are understood, and some prior thinking will help.

**Post-lab**
- transformations and knowledge claims: as for stages 1 and 2

At the conclusion of each laboratory exercise, conduct a discussion and refer to the vee, linking components of the vee to one another, thus allowing students a holistic view of the practical class.

**Post-test**

At the conclusion of the final laboratory exercise in week 4, or in the lesson immediately after, I will administer the post-test to students and instruct them to complete all questions.

**NB:** I will be present during a lesson in weeks 2 and 4, to observe vee-mapping implementation.
Knowledge

Concepts

Focus question

Experiment

Knowledge claims

Transformations

Results/Observations

Procedure